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The system for delivery of IR laser radiaton into high vacuum

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ABSTRACT: The system for insertion of a laser beam into the vacuum chamber of high-energy storage ring is described. The main part of the system is the high-vacuum viewport for the IR radiation, based on ZnSe or GaAs crystals. The design of the viewports is presented.

KEYWORDS: high vacuum, viewport, collider.

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Contents

1. Introduction

In experiments at e^+e^- colliders the high accuracy determination of the beam energy is crucial for lot of studies. The beam energy below 2 GeV can be precisely measured by the calorimetric method based on Compton backscattering of monochromatic $CO_2(CO)$ laser radiation on the beam (CBS method) [1].

In collider experiments, the CBS method was applied at VEPP-4M [2], the $\tau - charm$ factory BEPC-II [3] and at VEPP-2000 [4]. For insertion of the laser beam into the vacuum chambers of these colliders the laser-to-vacuum insertion system was developed. Here we report the design of the system.

2. Laser-to-vacuum insertion system overview

The delivery of the laser beam into the collider vacuum chamber is performed using the laser-to-vacuum insertion system. The system is the special stainless steel vacuum chamber with an entrance viewport and water cooled copper mirror (figure 1). The system provides extra-high vacuum, i.e. pressure of residual gas inside the chamber is less than 5×10^{-10} Torr. The viewport transfers IR laser light into the vacuum and visible synchrotron radiation (SR) light from the vacuum. The output light can be used to monitor the beam position. The copper mirror in the vacuum chamber reflects the light through an angle of 90°. After back-scattering, high energy photons return back to the mirror, pass through it and leave the vacuum chamber.

There are two types of viewports based on GaAs mono-crystal and ZnSe polycristal plates. Both viewports are manufactured using similar technology and provide:

1. baking out the vacuum system up to 250°C,
2. extra-high vacuum,
3. transmission spectrum from 0.9 up to 18 μm (GaAs viewport) and from 0.45 to 20 μm (ZnSe viewport).

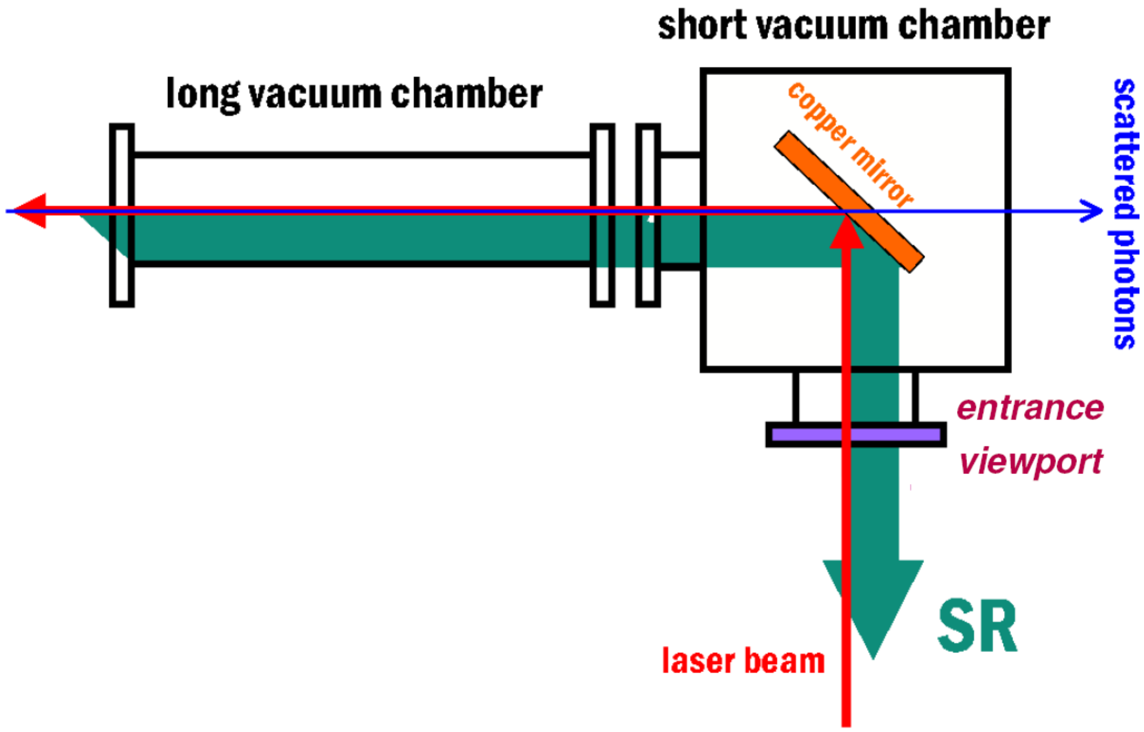

Figure 1. Simplified schematic of the laser-to-vacuum insertion assembly.

3. GaAs and ZnSe viewports

The viewport design is shown in figure 2. It includes a 304 L steel DN63 conflat flange and a GaAs or ZnSe crystal plate with diameter of 50.8 mm and thickness of 3 mm or 8 mm respectively. In order to compensate mechanically for the difference of the GaAs or ZnSe and stainless steel thermal expansion coefficients, the plate is brazed with pure soft lead to a titanium ring, which has been brazed with AgCu alloy to the stainless steel ring. The stainless steel ring is welded to the flange. The flat design of the viewport (thikness is less or equal to 25 mm) allows to use the viewports in the limited space of physical equipment.

To avoid evaporation of GaAs or ZnSe substance from the plates during brazing, they are covered with a 0.6 μm SiO_2 film using gas-phase deposition [5]. This film provide good adhesion of crystal plate with lead solder and allow to obtain reliable junction.

The transmission spectra of the plate before and after covering are shown in figure 3. The transmission of GaAs plate increases from 55 to 60 % at the CO_2 laser wavelength $\lambda = 10.6\mu$m and from 20 to 35% at $\lambda = 1\mu$m. In case of ZnSe plate the transmisson at $\lambda = 10.6\mu$m decrease from 75 to 62 %, but it turned out to be comparable with transmittance of GaAs plate. The advantage of ZnSe viewport is that it is transparent for the visible part of SR light. This makes the beam position monitoring more convenient.

The viewports were tested at vacuum stand with pressure less than 10^{-8} Torr. The tests have included several bakings out at 250°C for 8 hours. The temperature was raised and lowered at the rate 80°C per hour. After baking the air-tightness tests of viewports with sensitivity better than

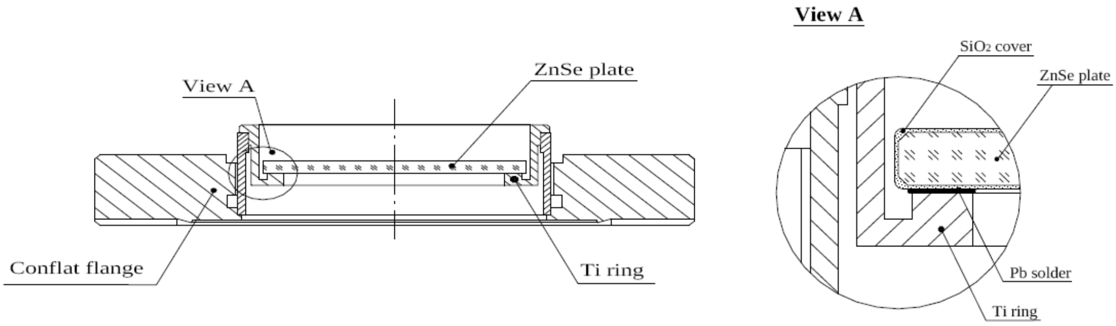

Figure 2. The design of ZnSe viewport.

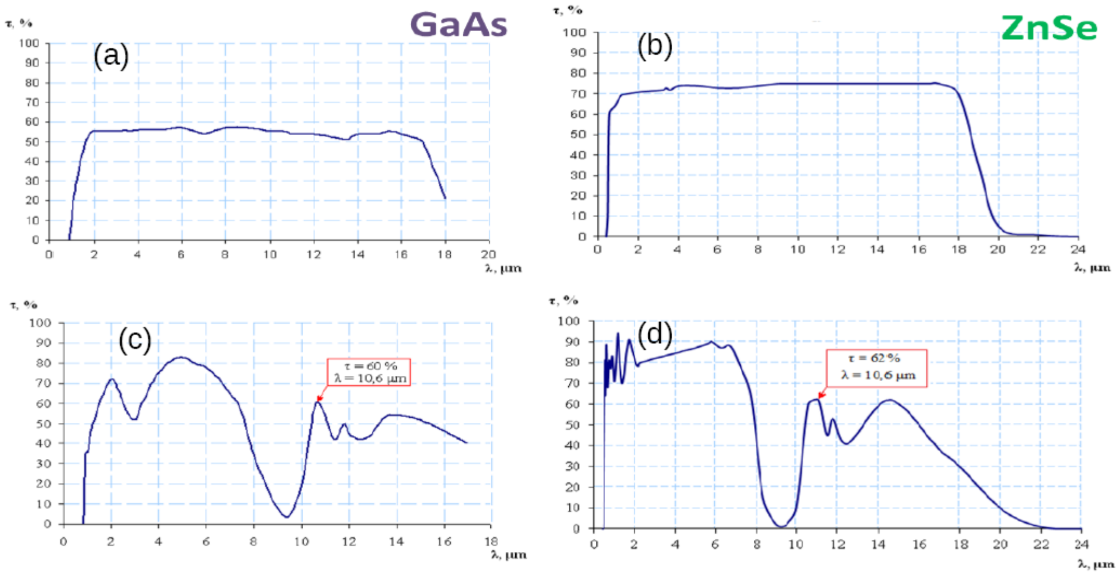

Figure 3. Transmittance spectra of uncoated GaAs and ZnSe crystals (a) and (b) and coated ones (d) and (c) by $0.6\mu m$ SiO_2 layer.

10^{-10} mbar·litre/s were performed. These studies have demonstrated that after numerous bakings the viewports have good vacuum properties and can be used at storage rings. Figure 4 shows the ZnSe an GaAs viewports ready for usage.

4. Copper mirror

The copper mirror design is shown in Figure 5. The mirror can be turned by bending the flexible bellows, so the angle between the mirror and the laser can be adjusted as necessary. Note, the copper mirror protects the viewport against high power synchrotron radiation due to low reflectivity of high energy photons (less than 1%) from a metallic surface. Synchrotron radiation (SR) photons heat the mirror. The extraction of heat is provided by a water cooling system. Cooling capacity is

Figure 4. Products GaAs and ZnSe viewports.

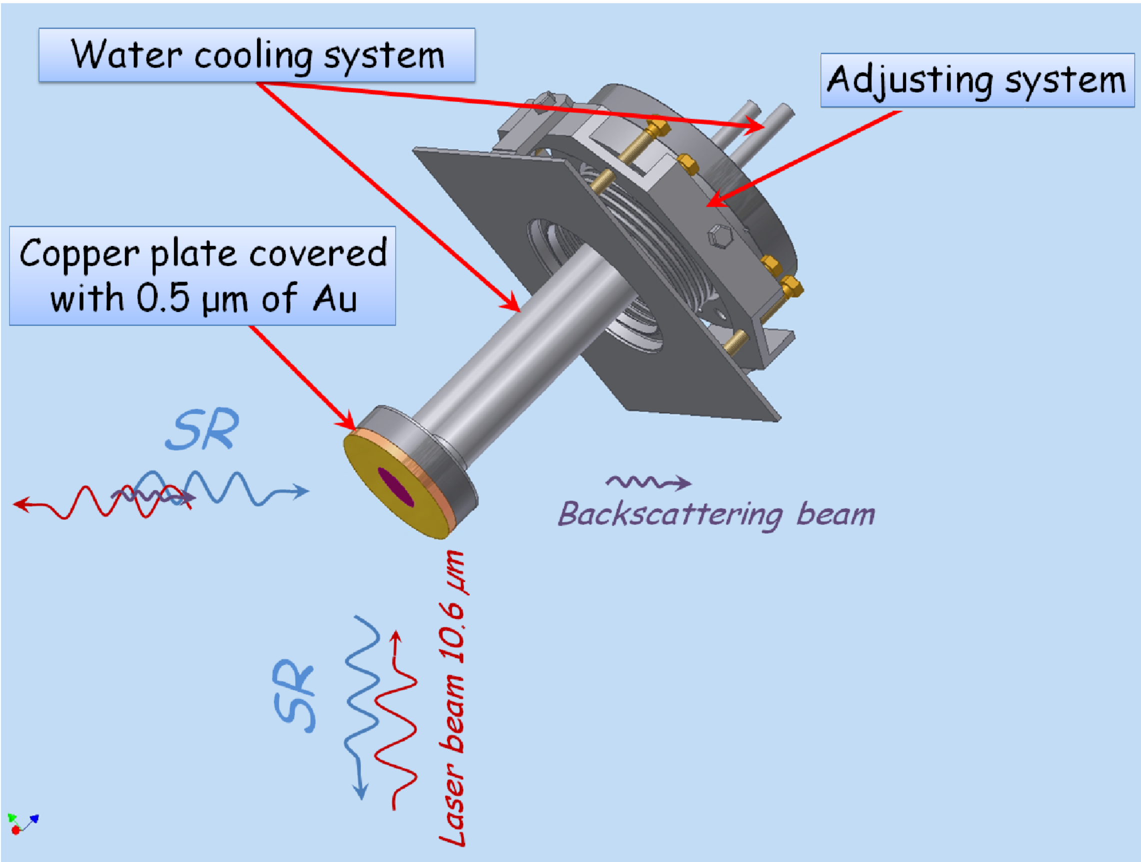

Figure 5. Copper mirror.

about 400 W. To prevent adsorption of residual gas molecules on the mirror surface, it is covered with a 0.5 μm thick gold layer.

5. Conclusion

The vacuum system for injection of laser beam in accelerator vacuum chamber was designed. The system provides insertion of the light with wavelength in the range from 0.45 to 20 μm. The system is used for calorimetric measurement of the VEPP-2000, VEPP-4M, BEPC-II colliders beams energy using CBS method. After installation of the system at colliders and backing out at $250^{\circ}C$ during 24 hours the pressure of about 10^{-10} Torr was obtained.

Acknowledgments

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